STATUS AND APPLICATIONS OF THE ALBERTA PHOTOGRAMMETRIC CONTROL SYSTEM

A.E. Balce
Alberta Bureau of Surveying and Mapping
Alberta Forestry, Lands and Wildlife*
Edmonton, Alberta

The Alberta Photogrammetric Control System (APCS) offers a wide range of applications including map compilation, quantity determination, map revision, land surveying and land information services. Accuracies of derived coordinates using an analytical stereoplotter are in the order of 0.11 to 0.21 m for horizontal and 0.10 to 0.17 m for vertical in urban areas. In rural areas, accuracies are 2.05 m for horizontal and 1.05 m for vertical. These accuracies are well within the standard accuracies of map products compiled using APCS data. The status of the system is presented.

Le Système de contrôle photogrammétrique de l'Alberta (APCS) offre une vaste gamme d'applications incluant la compilation cartographique, la détermination quantitative, la révision cartographique, l'arpentage et les systèmes d'information à référence spatiale. La précision des coordonnées dérivées lorsqu'on utilise un stéréorestituteur analytique varie, dans les régions urbaines, de 0.11 à 0.21 m en planimétrie et de 0.10 à 0.17 m en altimétrie. Dans les régions rurales, les précisions sont de 2.05 m en planimétrie et de 1.05 m en altimétrie. Ces précisions sont bien à l'intérieur des précisions standards des produits cartographiques compilés à l'aide de données APCS. On présente, ici, le statut du système APCS.

INTRODUCTION

The purpose of this paper is to summarize the status and applications of The Alberta Photogrammetric Control System, a new system at the Alberta Bureau of Surveying and Mapping (ABSM). This data base consists primarily of photogrammetric control data that are products of aerial triangulation. Aerial triangulation is a technique of positioning ground points using aerial photography, control information, and photogrammetric instrumentations.

Photogrammetric control data consist of terrain points precisely marked on the emulsion of an aerial photograph, and their respective X, Y and/or Z coordinates with respect to the ground datum.

*Formerly the Renewable Resources Sector, Alberta Energy and Natural Resources (ENR).

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This papers deals with a brief background and description of the APCS. Approximately 75 percent of the province is currently covered with APCS data, and the remainder is planned to be covered by 1988. Applications and accuracies of APCS data are also discussed.

BACKGROUND

The APCS was first proposed in 1980 as one of the objectives recommended by the Interdepartmental Committee on Surveying and Mapping [*Balce* 1985]. In 1981, APCS was identified as a subsystem of the Alberta Geographical Positioning System together with survey control and land survey subsystems [*Tessari* 1984].

APCS started to materialize in 1982 with the creation of the Photogrammetric Control Section responsible for the development, implementation and maintenance of the APCS. The section started as a one-man section (the author), with the acquisition of a precise point transfer device used for transferring photogrammetric control (PC) points from the original diapositives to the user's own set. This was followed with a comprehensive survey involving federal, provincial, city, and municipal agencies, regional planning commissions and private mapping companies, primarily to determine users' needs and requirements [*ENR* 1983]. In 1983, two more staff members were added to the section to handle the additional work load. As a result, PC materials were gathered and indexed from various agencies.

The computerized storage and retrieval system named APCS was designed, developed and implemented on the ABSMs VAX 11/785 during the fiscal year 1984–85. One full-time systems analyst was contracted for that purpose from the Alberta Public Works, Supply and Services in coordination with the Planning and Coordination Branch, ABSM. The system has been operational since April 1985.

SYSTEM DESCRIPTION

APCS is integrated with the Air Photo Record System (APRS) and they are jointly known as the Photogrammetric Control and Air Photo System (PCAP). The two systems have their own separate files (except the Lookup File which is shared), but are accessed using the same application software and data base management system. APRS is basically a storage and retrieval system of aerial photographs in the province flown for various departments of the Alberta government.

Data base

PC data are indexed in units of photogrammetric blocks that are defined as groups of stereomodels/bundles adjusted simultaneously. Block sizes vary up to a current maximum of 1707 models. Each block is assigned a consecutive indexing number called block adjustment (BA) number. At present, there are 179 blocks in the system.

The data base consists of the following master files:

- Lookup File is used for searching PC or air photo coverage based on location, scale, date of photography or any of their combination;
- Photogrammetric Project Summary Master File is used for providing detailed information regarding each block such as the agency owner, aerial photography, ground control surveys, aerial triangulation, original application, and other relevant information;

- Photogrammetric Adjusted Point File consists of adjusted and ground control coordinates with points stored uniquely in a block: data retrieved from this file may be used for plotting base control manuscripts;
- Photogrammetric Model Photo Point File consists of transformed ground coordinates on a model basis and photo coordinates on a photo basis: data retrieved from this file may be used for readjustment together with ground control data from the Photogrammetric Adjusted Point File; and
- Photogrammetric Project Photo File consists of camera orientation parameters that may be used for setting up stereomodels in an analytical stereoplotter without using PC points, or for computing stereoplotter settings for an analogue stereoplotter.

Software

- application software is coded in FORTRAN and POWERHOUSE, used for data entry, processing and retrieval: POWERHOUSE is a fourth generation language and a proprietary software product of Cognos Inc., Ottawa, Ontario, and is also used as the data base management system;
- the block adjustment system SPACE-M is used for readjusting and verifying data prior to data base loading;
- NXPLOT is used for plotting model diagrams; and
- SETUP is used for computing camera orientation parameters and instrument settings for selected analogue stereoplotters as required: SETUP and NXPLOT are proprietary software products of VTA Photogrammetric Consultants Ltd., Calgary, Alberta.

Hardware

The system is operating on the ABSM's VAX 11/785 accessed via two VT100 terminals. Output devices are one LA50 printer and a Hewlett Packard pen plotter.

PRODUCTS AND SERVICES

Materials that are generally available for each photogrammetric block are:

- triangulated diapositives and contact prints;
- National Research Council (NRC) camera calibration report;
- coordinates on listing and/or magnetic tape;
- project summary report; and
- photo and model diagram.

Although the province is now 75 percent covered with PC data, the excluded areas (see Figure 1) are not yet in the department's work plan. However, a request has been made to Surveys and Mapping Branch, Canada Energy, Mines and Resources (EMR), Ottawa for them to complete PC coverage in those areas in the future. An overview of the procedures associated with the services is given in *Balce* [1985].

APPLICATIONS

Map Compilation and Quantity Determination

The most common application of the system is to provide data for compiling new maps at scales and contents tailored to users' needs. For engineering applications, quantities

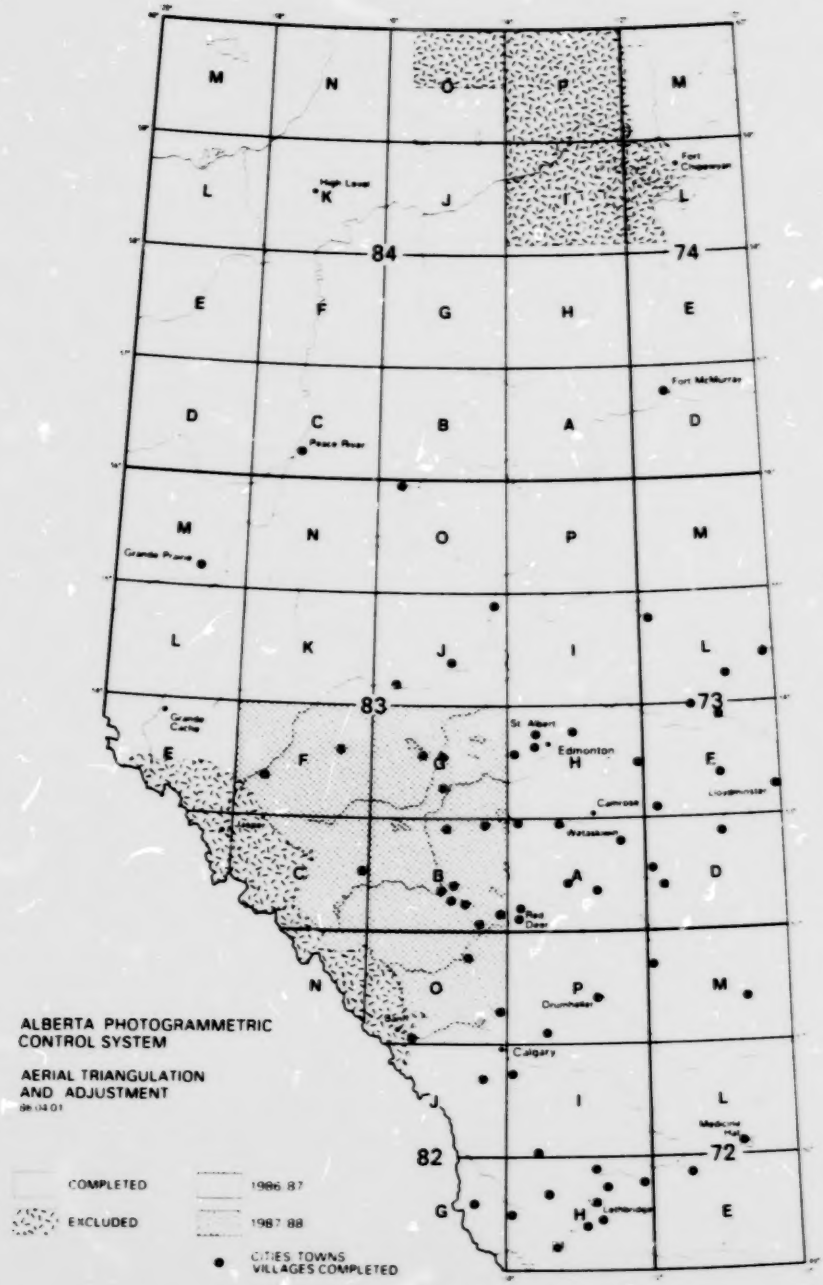

Figure 1: APCS index map

such as distances, directions, slopes, areas and volumes may be determined from the supplied materials.

Same photography

A new set of film diapositives and contact prints for most projects may be ordered at nominal fees from Maps Alberta, Program Support Branch, ABSM. With the new set of photographs, the user may transfer the PC points from the original diapositives to the user's own set. A precise point transfer device is available to users for this purpose. Assistance is provided to those who are not familiar with the transfer operations. Together with coordinates and camera calibration data, the user may compile a new map or determine quantities as required.

Different photography

In case of different photography, transfer of PC points may be difficult depending on the differences in scale and time of photography between the two sets of photographs. However, an effort should be made to transfer as many PC points as stereoscopy allows. If more points are needed, terrain features common to both photographs may be identified. Features to be used for planimetric orientation must be of sharp definition while those for vertical orientation must be on flat and bare ground. If more points are still needed, aerial triangulation may be performed with the new set of photographs using points derived from the original set as control points. Coordinates of selected features may be determined precisely by setting up the original set on an analytical stereoplotter and measuring the identified features. For example, the Aerial Survey Data Base of Surveys and Mapping Branch, EMR, Ottawa is intended to provide control for subsequent mapping at suitable scales from new photography [*Lapp et al.* 1978].

Map Revision

Conventional imagery

One way of updating a topographic map series (national/provincial/municipal) at any scale is to use aerial photography at a scale commensurate with the mapping scale. In this case, PC points may be transferred and/or common features identified as described in the preceding section (different photography). The new photographs can then be set up in a photogrammetric instrument and the existing map compared with the new photography for change detection and subsequent updating as required.

Satellite imagery

Another method of updating topographic map series is with the use of analogue/digital imagery obtained from space platforms. Stereoscopic transfer of PC points is generally not feasible due to large-scale differences between triangulated photos and satellite imageries. However, prominent ground features such as road intersections, can easily be identified on both imageries.

Examples of satellite imagery are:

(a) SPOT —
The Système Probatoire d'Observation de la Terre (SPOT) has just been launched by Centre Nationale d'Etudes Spatiales (CNES) in France. Hence, it has no real mapping application yet. However, based on designed spatial

resolutions. SPOT imagery should be capable of producing topographic maps at scales of 1:50 000 or smaller with contour intervals of 40 m or greater [*Welch* 1985]. The Institute Géographique National (IGN) in France carried out an experiment using simulated SPOT images and obtained accuracies of 10 m in planimetry and 15 m in elevation. It has been concluded that SPOT will be suitable for 1:100 000 scale mapping [*Doyle* 1984].

(b) Large Format Camera (LFC) —
LFC is the major component of NASA's Orbiter Camera Payload System and is mounted in the bay of the space shuttle [*Lucas et al.* 1986]. Based on actual test results, LFC imageries are suitable for planimetric map compilation at a scale of 1:50 000 or smaller and contouring with 75 m contour interval or greater [*Newton and Derenyi* 1986].

(c) Landsats —
Landsat imagery has been used for revising the 1:250 000 National Topographic Series of Surveys and Mapping Branch, EMR, Ottawa [*Lapp et al.* 1978, *Gregory et al.* 1982, *Gregory and Moore* 1986]. Using imagery from the Thematic Mapper of Landsat 4, resampling of digital data based on ground control points resulted in accuracy commensurate with 1:100 000 scale mapping or smaller [*Doyle* 1984]. In separate experiments, imageries from Landsats 4 and 5 achieved accuracy commensurate with 1:50 000 scale mapping or smaller [*Welch et al.* 1985, *Borgeson et al.* 1985].

Surveys of Canada Lands

As per Section 14, Canada Oil and Gas Land Regulations, the ground position of a grid area, permit area, lease area, section, unit or well may, at the discretion of the surveyor general, be surveyed by reference to a physical feature, the geographical position of which has been determined by photogrammetric process among other surveying techniques. Moreover, natural boundaries and topographical features on plans of survey may be plotted by photogrammetric methods [*EMR* 1979].

Land Information System

A basic component of a land information system is a common coordinate referencing system to which all data are tied for consistency and compatibility. There are several methods of determining positions of land data, depending on the accuracy required. One of these methods is the use of "controlled aerial photography translated to ground identifiable points using analytical point positioning systems" [*Logan* 1981]. Analytical stereoplotter systems offer the best photogrammetric technique for urban information systems because of their versatility and accuracy [*Jaksic* 1972, *Cremoni* 1980].

ACCURACIES OF DERIVED DATA

The accuracy of coordinates dervied using data from APCS is determined by the following factors:

- Aerial triangulation standard deviation σ_{AT}
- point transfer standard deviation σ_{trans}
- model setup standard deviation σ_{setup}
- point measurement standard deviation σ_{meas}

The variance σ^2_{XI} may be estimated as the sum of variances, σ^2_{TP} and σ^2_{GC} where σ_{TP} is the RMS of tie point residuals after block adjustment and σ_{GC} is the RMS of ground control point residuals after block adjustment. σ_{trans} may be estimated to be 6 μm at image scale if PC points are transferred to a duplicate set of photography [*Balce* 1985]. If PC points are transferred to a different set, transfer error can be in the order of 12 to 21 μm [*Thompson* 1979] depending on the difference in scale and time of photography between the two sets. Point transfer error has no significant effect on vertical accuracy because PC points are usually located on flat ground. σ_{setup} may be estimated to be the RMS of photogrammetric ground control point residuals after exterior orientation. σ_{meas} may be estimated to be 3 μm at image scale for planimetric positioning using an analytical stereoplotter. For vertical positioning, σ_{meas} may be estimated to be equal to σ_{setup}.

Applying the law of propagation of variances and disregarding correlations, the variances of coordinates derived using APCS data are:

$$\sigma^2_{XY} = (\sigma_{TP})^2_{XY} + (\sigma_{GC})^2_{XY} + (\sigma_{trans})^2_{XY} + (\sigma_{setup})^2_{XY} + (\sigma_{meas})^2_{XY} \quad (1)$$

for planimetric coordinates, and

$$\sigma^2_Z = (\sigma_{TP})^2_Z + (\sigma_{GC})^2_Z + 2(\sigma_{setup})^2_Z \quad (2)$$

for elevations.

Accuracies for photo scales 1:4000 and 1:8000 used for municipal mapping and 1:60 000 for provincial mapping are estimated for illustration purposes (see Tables 1 and 2). Accuracies for other photo scales may be similarly estimated. Accuracies shown are all at the one sigma level. σ_{TP} and σ_{GC} are based upon the results of aerial triangulation using analytical stereoplotters and adjustments using the program SPACE-M. σ_{setup} is based upon the average RMS of exterior orientation results of three to five stereomodels using analytical stereoplotters. For example, with the use of municipal photogrammetric control from photographs at scales of 1:4000/1:8000, σ_{XY} = 0.11/0.21 m, and σ_Z = 0.10/0.17 m. Provincial photogrammetric control from 1:60 000 aerial photography is capable of yielding accuracies of σ_{XY} = 2.05 m and σ_Z = 1.05 m.

Table 1: planimetric standard deviations

Photo Scale	$(\sigma_{TP})_{XY}$ (m)	$(\sigma_{GC})_{XY}$ (m)	$(\sigma_{trans})_{XY}$ (m)	$(\sigma_{setup})_{XY}$ (m)	$(\sigma_{meas})_{XY}$ (m)	σ_{XY} (m)
1:4000	0.03	0.08	0.02	0.07	0.01	0.11
1:8000	0.08	0.12	0.05	0.14	0.02	0.21
1:60 000	0.62	1.77	0.36	0.73	0.18	2.05

Table 2: vertical standard deviations

Photo Scale	$(\sigma_{TP})_Z$ (m)	$(\sigma_{GC})_Z$ (m)	$(\sigma_{setup})_Z$ (m)	σ_Z (m)
1:4000	0.03	0.06	0.05	0.10
1:8000	0.06	0.11	0.08	0.17
1:60 000	0.49	0.72	0.42	1.05

These accuracies may be compared with standard accuracies of map products (see Tables 3 and 4). It can be noted that using triangulated photographs, accuracies are higher by factors of 3.5 to 8.5 for planimetric positioning. For vertical positioning, accuracies are higher by factors of 1.5 to 3.0. Hence, it is far more accurate to use triangulated photographs than their respective map products.

Table 3: comparison with standard accuracies of planimetric maps

Photo Scale	Map Scale	σ_{map} (m)	σ_{XY} (m)	σ_{map}/σ_{XY}
1:4000	1:1000	0.36	0.11	3.3
1:8000	1:5000	1.78	0.21	8.5
1:60 000	1:20 000	7.12	2.05	3.5

Note: $\sigma_{map} = \dfrac{0.54\ (MS)\ \sqrt{2}}{1000\ (2.146)}$

where MS = map scale denominator.

For details see ASPRS [1985].

Table 4: comparison with standard accuracies of contour lines

Photo Scale	Contour Interval (m)	σ_{elev}* (m)	σ_Z (m)	σ_{elev}/σ_Z
1:4000	0.5	0.15	0.10	1.5
1:8000	1.0	0.30	0.17	1.8
1:60 000	10.0	3.04	1.05	2.9

*See ASPRS [1985] for details.

CONCLUSIONS AND RECOMMENDATIONS

The Alberta Photogrammetric Control System is now fully operational and has contributed to the compilation of new maps tailored to users' needs. However, potential applications such as quantitative determination (e.g., volumes, areas), map revision, land surveying and other land information requirements have not yet been fully exploited. For maximum accuracies, the use of analytical stereoplotters is recommended. Planimetric accuracies of 0.11 to 0.21 m, and 2.05 m can be attained using municipal and provincial photogrammetric control data, respectively. Vertical accuracies of 0.10 to 0.17 m, and 1.05 m can be attained using municipal and provincial PC data, respectively. These accuracies are well within the standard accuracies of map products compiled using APCS data. Potential economic benefits when using the system to its fullest capability are not easy to estimate. However, users are encouraged to become better acquainted with the services offered by the system to realize its full potential.

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Antonio E. Balce received his B.Sc. in geodetic engineering from the University of the Philippines, Quezon City in 1970. Upon graduation, he was appointed instructor in geodetic engineering at the Saint Louis University, Baguio City, Philippines. In 1974, he received his M.Sc. in photogrammetric engineering from the International Institute for Aerial Survey and Earth Sciences (ITC), Enschede, The Netherlands.

Upon leaving ITC, he worked for J.D. Barnes Limited, Willowdale, Ontario as a survey technologist. In 1977 he was appointed senior mapping technologist by Alberta Energy and Natural Resources, Edmonton, a position he held for six months. He then held a number of survey/photogrammetric engineering positions in the department. Since 1982, he has been the head of the Photogrammetric Control Section, Survey Control Branch, Alberta Bureau of Surveying and Mapping, Alberta Forestry, Lands and Wildlife, Edmonton.

He is a member of the Association of Professional Engineers, Geologists and Geophysicists of Alberta, the Association of Canada Lands Surveyors, the Canadian Institute of Surveying and Mapping, and the American Society of Photogrammetry and Remote Sensing.□